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Graphemic, Associative, and Syntactic Priming Effects at a Brief Stimulus Onset Asynchrony in Lexical Decision and Naming

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The present set of experiments investigated graphemic, associative, and syntactic priming effects in both a lexical decision and a naming task. In all experiments, a three-word masking procedure (word–prime–target) with a 60-ms stimulus onset asynchrony (SOA) between prime and target was used to limit strategic effects. Targets that were graphemically similar or identical to primes were facilitated in both tasks. However, target items preceded by associatively related or syntactically appropriate primes were significantly facilitated only in lexical decision. These data are discussed in comparative terms with reference to current models of word recognition in which backward priming effects and postlexical familiarity processes are operative.

Word recognition is a necessary component of sentence comprehension. Recent research has used response latencies (reaction times) to delineate the processes involved in word recognition (see Rayner & Pollatsek, 1989, for a summary). However, it is difficult to make definitive statements about these processes because different experimental methodologies as well as different tasks are often used.

The present series of experiments provide evidence regarding three well-established types of priming effects in two traditional tasks. Importantly, a single experimental methodology was used in all experiments. Additionally, in the present experimental procedure, a short stimulus onset asynchrony (SOA) between prime and target was employed, and the priming stimulus was forward and backward masked to limit strategic influences. In order to examine the operation of the lexical system, the present experiments investigated how graphemic, associative, and syntactic information is activated during lexical access.

Graphemic Priming Effects

One successful method of investigating the type of orthographic information required for word recognition in reading has resulted from graphemic priming experiments. Evett and Humphreys (1981) and Humphreys, Evett, Quinlan, and Besner (1987) used a four-field masking procedure to investigate graphemic priming effects in word recognition. In these experiments, prime and target pairs were preceded and followed by a pattern mask (mask–prime–target–mask) presented in such a way that primes could not be identified. The subject's task was simply to identify the target that was presented on each trial. With this methodology, Evett and Humphreys (1981) found a graphemic priming effect that was independent of the *physical* identity of prime and target items because primes were displayed in lowercase and targets in uppercase letters (mask–prime–TARGET–mask). Although this priming effect was stronger for graphemically *identical* prime–target pairs than for graphemically *similar* pairs, both conditions showed substantial facilitation. Humphreys et al. (1987) also found that identification of targets whose primes were graphemically related was facilitated regardless of whether the prime was a word or a nonword. Studies dealing with the integration of information across eye movements have also found graphemic priming effects (Balota & Rayner, 1983; Rayner, McConkie, & Ehrlich, 1978; Rayner, McConkie, & Zola, 1980). On the basis of these data, Evett and Humphreys (1981), Humphreys et al. (1987), and Rayner et al. (1980) have argued that the graphemic priming of target items results from the activation of an abstract orthographic representation. This abstract representation can be activated by graphemically similar as well as graphemically identical primes.

However, Forster and Davis (1984), using a three-word masking procedure (explained in detail below), obtained contrary results. Although they observed identity priming in high and low frequency words in a lexical decision task, they did not find graphemically similar priming. Moreover, nonword targets did not show any priming effects. Forster and Davis (1984) argued that priming occurred only when there was repeated access of the same lexical item and therefore was not due to sublexical letter repetition processes because neither graphemic similarity of prime and target words nor the use of prime and target nonwords produced priming in their experiments.

Recently, however, Forster, Davis, Schoknecht, and Carter (1987) and Forster (1987) modified these conclusions when they found that graphemically similar but nonidentical forms produced priming effects in longer words or words located in low density neighborhoods. On the basis of these results, they have suggested a more dynamic graphemic priming effect in

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which entries are not simply "open" or "closed" to higher level processing as in a table look-up theory, but are partially activated, as in an activation model, by letter detectors coded for position.

Associative Priming Effects

Priming effects have also been found when the prime is associatively related but not physically (visually or auditorily) similar to a subsequent target item (for a review, see Neely, in press). In a well-known experiment, Meyer and Schvaneveldt (1971) demonstrated that lexical decisions are facilitated by the prior processing of an associated word. For example, subjects are significantly faster in deciding that a target letter string (e.g., *nurse*) is a word when the preceding stimulus is an associatively related word (e.g., *doctor*) compared to an unrelated word (e.g., *bread*).

Warren (1977) exploited these associative effects in an attempt to determine exactly when priming can be observed. He used pronunciation time as a measure of priming. He successively presented prime and target, one centered above the other. Upon onset of the target, the prime was masked. Warren (1977) found that there was no facilitation in naming responses for associatively related stimuli at short prime durations (75 ms and 112.5 ms).

Using a lexical decision task, Fischler and Goodman (1978) extended these results to a shorter SOA. They demonstrated that associative priming can occur rapidly, at SOAs as short as 40 ms. However, this effect seemed to be restricted because subjects taking a long time when responding to "more difficult" target words showed substantial facilitation at a 40-ms SOA, whereas faster subjects did not. However, Fischler and Goodman (1978) also found that, at 90-ms SOAs, these associative effects disappeared—prime words did not influence associatively related targets. Awareness of the prime word at the 90-ms SOA seemed to interfere with the priming effects.

Taken together, the results of Warren (1977) and Fischler and Goodman (1978) suggest that associative priming effects can occur at very short SOAs (40 ms) when prime recall is impossible, but, at intermediate SOAs (e.g., 75–90-ms), prime recall causes these priming effects to disappear. However, it should be noted that there were also task differences between these studies that may have contributed to the observed pattern of results.

Syntactic Priming Effects

In addition to these associative priming studies, there have been many experiments investigating "higher level" contextual effects on word recognition processes. These studies have shown that both syntactic and pragmatic contextual information facilitate lexical processing (e.g., Fischler & Bloom, 1979; Sanocki & Oden, 1984; Schuberth & Eimas, 1977; Stanovich & West, 1983; West & Stanovich, 1982), with some researchers claiming that syntactic processing precedes semantic plausibility judgments (e.g., Rayner, Carlson, & Frazier, 1983) and others proposing that both types of information interact in sentence processing (e.g., Marslen-Wilson & Tyler, 1980; Tyler & Marslen-Wilson, 1977). However, only a few studies have simply examined the effects of syntactic context alone.

The syntactic priming effect studied by Goodman, McClelland, and Gibbs (1981) used a one-word prime "context" for a following target item. Prime words (e.g., articles and pronouns) were used that unequivocally predicted the syntactic class of the target (i.e., noun and verb, respectively). In their experiments, primes and targets were presented at SOAs of 500 ms. Goodman et al. (1981) reported that lexical decision latencies to targets were significantly shorter when they were preceded by a syntactically appropriate word (e.g., *my* oven) compared to a syntactically inappropriate word (e.g., *he* oven).

Seidenberg, Waters, Sanders, and Langer (1984) presented the stimuli of Goodman et al. (1981) in both a lexical decision and naming task, using a slightly different procedure involving a 600-ms SOA. Seidenberg and colleagues replicated the lexical decision results (a significant 13-ms priming effect for syntactic context) but found only a marginally significant 5-ms facilitation effect in pronunciation. Seidenberg et al. (1984) claimed that naming tasks may not be as sensitive to syntactic context. They explained the results in terms of the relative susceptibility of the lexical decision task to postlexical decision processes that allow higher level syntactic information to interact with the product of lexical access processes.

Wright and Garrett (1984), using a more controlled stimulus set, further investigated syntactic priming effects. In their experiments, targets were either nouns or verbs and syntactic context consisted of the initial part of an English sentence. Subjects were presented with sentence fragments followed by a target and were required to make a lexical decision. SOAs were at least 600 ms in duration. Wright and Garrett (1984) found strong evidence for syntactic contextual effects. That is, main verb targets were responded to faster when preceded by sentence contexts ending in a modal verb compared to a preposition; likewise, noun targets were responded to faster when preceded by sentence contexts ending in a preposition compared to a modal verb. Thus, Wright and Garrett (1984) found robust differences in reaction times resulting from syntactically appropriate versus syntactically inappropriate contexts in a lexical decision task.

Finally, West and Stanovich (1986) conducted a series of experiments examining the effects of syntactic context in naming as well as lexical decision. Target presentations were triggered by the experimenter after complete articulation of the prime stimulus. Using the stimuli of Wright and Garrett (1984), West and Stanovich (1986) demonstrated strong syntactic effects in both tasks. Moreover, these priming effects, notably in the naming task, were maintained under a variety of methodological manipulations, such as differing task requirements or contextual presentation rates. In all cases, responses to both noun and verb targets were faster in both lexical decision and naming tasks when they were syntactically appropriate continuations of prior sentence contexts, clearly demonstrating a pervasive influence of syntactic information on word recognition processes.

Although syntactic priming effects have been consistently demonstrated in both lexical decision tasks and naming tasks, all of these syntactic priming experiments allowed considerable time between processing the prime context and the target stimulus. Because the time course of processing the prime and target is critical in determining the locus of effects, it is difficult to make claims concerning the level of processing at which these syntactic priming effects occurred.

In sum, the results of the previous experiments examining graphemic, associative, and syntactic priming effects are difficult to interpret not only within but also across priming domains. Often, several critical factors simultaneously vary across studies.

The present series of experiments examined graphemic, associative, and syntactic priming effects in both a lexical decision and a pronunciation task, making use of a particular method of presentation, the three-word masking paradigm, devised by Forster and Davis (1984). In this procedure, three stimuli are presented sequentially in the same location. The first stimulus, a "neutral" word, is displayed for 500 ms, the prime for 60 ms, and the target until the subject makes a response. All interstimulus intervals (ISIs) are 0 ms. The result of such a procedure is that the second item, the prime, is masked in a forward and backward direction by the first and third items, respectively.

Such a procedure offered several advantages. The three-word masking paradigm provided a sensitive measure of processing by limiting the duration of the prime and eliminating the interval between the prime offset and target onset. In earlier studies, the temporal presentation of prime and target was often selected without serious motivation. Some experiments controlled prime duration while allowing long ISIs before target presentation (e.g., Marcel, 1980), whereas other studies restricted ISIs while allowing primes to be presented for relatively long durations (e.g., Swinney, 1979, in a cross-modal task). Many claims based on these reaction time data assume that the testing procedures accurately measure typical word recognition processes. However, reaction times by their very nature only represent the final output of a potential multiplicity of interacting processes. Nevertheless, by carefully controlling processing time, reaction time data can be salvaged. If the amount of time allowed for processing is radically restricted, additional processes that can occur are, consequently, also limited.

An additional advantage of the present experiments was that they employed a multitask approach. Specifically, a lexical decision task and a pronunciation task were used to investigate lexical processing. Different experimental tasks may tap different components of the language processing system, thereby providing a way of selectively analyzing these subprocesses.

Finally, the present experiments investigated several "levels" of the lexicon in a comparable fashion by using a single experimental paradigm. In the field of word recognition, methods used to test one level of the lexicon are often not used in examining other levels. In the present experiments, graphemic, associative, and syntactic relations were investigated using an identical procedure in order to determine how and when these types of information are extracted in the processing sequence. Graphemic analyses of stimuli are typically thought to be performed early in processing; associative relatedness may structure the lexicon itself; and syntactic information has generally been assumed to be operative subsequent to lexical access processes. The present experiments addressed these particular claims concerning the structures and processes involved in word recognition in order to obtain a more unified picture of lexical organization and lexical access processes.

Three pairs of experiments were conducted, examining the distinctive graphemic, associative, and syntactic aspects of the lexical system. Each pair of experiments consisted of a lexical decision task and a naming task, resulting in a total of six experiments. The first two experiments explored graphemic priming effects, the next two explored associative priming effects, and the last two explored syntactic priming effects.

Experiments 1 and 2: Graphemic Priming Effects

Experiments 1 and 2 investigated identity and graphemic priming effects using the three-word masking paradigm in order to explore an early stage of word recognition. Identity priming involves a prime that is exactly the same as the target item, whereas graphemic priming involves a prime that is similar in spelling to the target item.

Similar experimental conditions to those used by Forster and Davis (1984) were contrasted, but baseline conditions were also included to determine whether these effects were facilitatory or inhibitory. If graphemic priming is effective, response latencies to target stimuli in graphemically identical or graphemically similar priming conditions should be facilitated relative to the baseline and control conditions. If not, it is presumed that the lexical access of target stimuli is not influenced by the graphemic similarity of prime and target at these short SOAs. Two additional variables (frequency and form class membership) of target items were also examined to determine whether they interacted with the experimental conditions. Lexical decision times as well as pronunciation latencies were used as dependent measures to determine whether demands affected the graphemic priming effects. Experiment 1 examined graphemic priming effects using a lexical decision task and Experiment 2 employed a naming task.

Experiment 1

Method

Subjects. Twenty subjects attending Brown University were paid to participate in the experiment. All were native speakers of American English with normal or corrected-to-normal visual acuity. All had normal reading skills. No subject participated in more than one of the present experiments.

Stimuli. The stimuli consisted of 200 triplets in which the first item was a word mask, the second item was the prime, and the third item was the target. The mask and prime were presented in lowercase letters and the target appeared in uppercase letters. A complete list of all stimuli used in Experiment 1 is provided in Appendix A. Overall, mask, prime, and target items were controlled for frequency, form class membership, word length in letters, and number of syllables (a detailed description of the stimuli is given in Sereno, 1988). Furthermore, semantic predictability of these triplets was low, thus isolating the graphemic variable as the variable of interest.

There were 200 target stimuli—100 word and 100 legal nonword targets. For the word targets, half were high frequency (mean frequency of 175 per million) and half were low frequency (mean frequency of 7 per million) (Francis & Kucera, 1982). Also, half of each of the high and low frequency targets were pure nouns (used only as nouns with no occurrences as a verb), and half were pure verbs (used only as verbs with no occurrences as a noun). The target words were also matched for word length and number of syllables. There were 3 four-letter, 7 five-letter, and 15 six-letter words in each of the high frequency noun, the high frequency verb, the low frequency noun, and the low frequency verb target groups, of which 7 were monosyllabic and 18 were bisyllabic. All nonword targets were legal nonwords. The nonword targets were matched to the word targets in word length and number of syllables.

There were five prime conditions for the word targets (asterisk, opposite, different, similar, and identical). Examples of each of the conditions for word targets are given in Table 1. Primes were constructed so that they were never longer in number of letters than the mask or target words.

In the asterisk condition, the prime was a string of four asterisks (****). For the opposite and different conditions, primes were constructed so that there was no letter overlap with mask or target items. For the opposite condition, the primes consisted of legal nonwords. In the different condition, primes were words that were matched to the target words in frequency of occurrence, form class membership, word length, and number of syllables. For the similar condition, the primes differed from the target words by only one medial vowel letter. All primes in this condition were legal nonwords. In the identical condition, the prime was the same word as the target.

A congruent set of prime conditions (asterisk, opposite, different, similar, and identical) was constructed for the nonword targets (see Table 1). Just as with the word targets, the asterisk condition for the nonword targets consisted of a prime of four asterisks. In the opposite condition, the prime for the nonword targets was a word that had no letter overlap with the target. For the different condition, the primes were all nonwords that differed from the nonword targets. In the similar condition, the primes were graphemically similar but not identical to the nonword targets. The primes differed from the targets by either one, two, or three letters. All primes in the similar condition were words. In the identical condition for nonword targets, the prime was the same as the target. Therefore, all primes in the identical condition were nonwords.

The mask or first word of the triplet was also controlled. Two separate lists (List A and List B) were used to minimize the effect of mask word on trials. Both lists were matched to target items for frequency of occurrence, form class membership, word length, and number of syllables.

Table 1
Examples of the Five Treatment Conditions Used in Experiment 1 for Both Word Targets and Nonword Targets

	Condition				
Target	Asterisk	Opposite	Different	Similar	Identical
		Word targets			
Mask word	shine	shine	shine	shine	shine
Prime	****	pasil	enter	beist	beast
Target	BEAST	BEAST	BEAST	BEAST	BEAST
		Nonword targets			
Mask word	climb	climb	climb	climb	climb
Prime	****	month	blask	plate	plave
Target	PLAVE	PLAVE	PLAVE	PLAVE	PLAVE

Procedure. Stimulus timing was controlled by an IBM personal computer (XT) and stimuli were presented on a Panasonic video monitor (model TR-930) in which the timing of the display was synchronized with the position of the raster. Subjects were instructed to make a lexical decision to the stimulus in uppercase letters. They were to press one of two response buttons in front of them with the index finger of their dominant hand. Subjects were to respond as quickly and as accurately as possible.

Stimuli were presented at a fixed rate. Each trial began with a mask (in lowercase) presented for 500 ms, immediately followed by a prime (in lowercase) presented for 60 ms, and then concluded with a target (in uppercase) that remained until the subject pressed one of the two buttons on the response box. Reaction time was measured from the onset of the target. Immediately after a response, the target disappeared from the screen. The screen then remained blank for 2 s prior to the start of the next trial. This entire sequence was repeated for each trial.

Every subject was given a total of 10 practice trials sampled from all the prime conditions in order to introduce them to the procedure. These practice items were not used in the experiment.

The experiment involved a counterbalanced design in which no subject saw any mask word, prime, or target more than once in the test. Five different sets of test materials were used. Each subject saw 200 test stimulus trials, which included 40 trials in each of the five experimental conditions, half with word targets and the remaining half with nonword targets.

To minimize the effect of extraneous variables, two additional controls were instituted. First, the placement of the response buttons was counterbalanced across subjects, with half of the subjects having the "word" button on the left and the remaining subjects having the "word" button on the right. Second, to ensure that the initial word was acting simply as a mask, half of the subjects saw one set of mask words (List A) preceding word targets and a different set (List B) preceding nonword targets, whereas the other half saw the reverse.

Results

Mean lexical decision latencies and error rates for the five different conditions of Experiment 1 are provided in Table 2. The data in all experiments were analyzed by analysis of variance (ANOVA), with both subjects ($F1$) and items ($F2$) as random variables. All means presented are taken from the subject analyses. For all experiments, all mistakes and scores greater than three standard deviations from each subject's mean were discarded. There were 225 errors in this experiment, resulting in an overall error rate of 5.6%.

Because there were no significant main effects or interactions involving the list or button variables, data were collapsed over these variables. A 5 × 2 × 2 ANOVA (Condition × Frequency × Form Class) performed on the lexical decision latencies for the word targets revealed a main effect for condition, $F1(4, 76) = 13.65$, $MS_e = 3{,}030$, $p < .001$, and $F2(4, 384) = 12.09$, $MS_e = 4{,}420$, $p < .001$, with Newman–Keuls post hoc tests revealing that the identical condition was significantly different from all other conditions (asterisk, opposite, different, and similar) ($p < .01$) and that the similar condition was significantly different from the opposite and different conditions ($p < .05$).

The results showed that, in a lexical decision task, targets preceded by identical primes were greatly facilitated relative

Table 2
Mean Lexical Decision Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Five Treatment Conditions Used in Experiment 1 for Both High Frequency and Low Frequency Word Targets and for Nonword Targets

Condition	Frequency	Latency	Error rate
	Word targets		
Asterisk	H	617	4.0
	L	675	12.5
Opposite	H	623	1.5
	L	702	10.5
Different	H	621	3.5
	L	694	11.0
Similar	H	607	3.0
	L	666	10.0
Identical	H	581	1.5
	L	630	7.0
	Nonword targets		
Asterisk	—	683	4.5
Opposite	—	689	4.3
Different	—	678	5.5
Similar	—	679	4.3
Identical	—	649	5.5

Note. H = high-frequency word targets; L = low-frequency word targets.

to targets preceded by a baseline condition (asterisks), a nonword prime, a graphemically dissimilar word prime, or even a graphemically similar nonword prime. Moreover, targets preceded by graphemically similar primes were facilitated relative to targets preceded by both graphemically dissimilar word primes and nonword primes. Graphemically related prime–target pairs tended to be facilitated relative to the neutral control, whereas graphemically dissimilar word and nonword primes tended to inhibit target items relative to the neutral control condition. The combined effect of this facilitatory and inhibitory priming relative to the baseline condition resulted in sizable and significant reaction time differences between the graphemically related and graphemically unrelated conditions for word targets.

The analysis also revealed that high frequency target words (610 ms) had significantly faster lexical decision latencies than low frequency targets (673 ms), $F1(1, 19) = 168.91$, $MS_e = 2{,}367$, $p < .001$, and $F2(1, 96) = 71.49$, $MS_e = 8{,}394$, $p < .001$. All other interactions among the factors were not significant.

A one-way ANOVA (Condition) performed on the nonword data revealed a main effect, $F1(4, 76) = 6.69$, $MS_e = 699$, $p < .001$, and $F2(4, 396) = 7.19$, $MS_e = 3{,}499$, $p < .001$, with Newman–Keuls post hoc tests showing that the identical condition was significantly different from all other conditions (asterisk, opposite, different, and similar) ($p < .01$). That is, nonword targets preceded by identical primes were facilitated relative to targets preceded by the baseline condition, a graphemically different word prime, a graphemically different nonword prime, and a graphemically similar prime. However, nonword targets preceded by graphemically similar primes were not facilitated relative to any of the other prime conditions. These results clearly show the existence of effective identity priming for nonword targets.

A combined word/nonword analysis revealed that word targets (640 ms) were significantly faster than nonword targets (676 ms), $F1(1, 19) = 16.73$, $MS_e = 3{,}802$, $p < .001$, and $F2(1, 198) = 23.02$, $MS_e = 12{,}043$, $p < .001$.

An analysis of the error data was also conducted. For the word targets, a two-way ANOVA (Condition × Frequency) revealed that there were fewer errors for high frequency targets (27 errors) than for low frequency targets (102 errors), $F1(1, 19) = 27.30$, $MS_e = 1.03$, $p < .001$, and $F2(1, 98) = 13.98$, $MS_e = .80$, $p < .001$. There were no other significant main effects or interactions. For the nonword targets, a one-way ANOVA (Condition) did not reveal any significant effects for the error data.

Experiment 2

Method

Subjects. Ten new students from the subject pool described in Experiment 1 participated in the experiment.

Stimuli. The stimuli for Experiment 2 were the word stimuli (100 word triplets) used in Experiment 1.

Procedure. The procedure was identical to that used in Experiment 1 except that subjects were instructed to *pronounce* the target word as fast and as accurately as possible. The target remained on the screen until the subject's vocal response triggered a voice-activated relay (Gerbrands model G1341T) by means of a Dynamic microphone (model 2302) located on a stand in front of the subject. When the subject responded, the target disappeared from the screen. Subjects' naming responses were recorded on a Panasonic cassette tape recorder for later analysis. All other procedures were identical to those used in Experiment 1.

Results

Mean naming latencies and error rates for the five different conditions of Experiment 2 are given in Table 3. Trials in which the subject pronounced the wrong word or pronounced the word incorrectly and trials in which the subject accidentally triggered the microphone (e.g., by hitting the table or by prefacing pronunciations with an "uh") were scored as errors. There were 39 errors in this experiment, resulting in an overall error rate of 3.9%.

Because there were no significant effects involving the list variable, data were summed over this variable and a 5 × 2 × 2 ANOVA (Condition × Frequency × Form Class) was performed on the naming latencies for the word targets. This analysis revealed a main effect for condition, $F1(4, 36) = 25.24$, $MS_e = 1{,}024$, $p < .001$, and $F2(4, 384) = 20.06$, $MS_e = 3{,}183$, $p < .001$. Newman–Keuls post hoc tests revealed that the identical condition was significantly different from all other conditions (asterisk, opposite, different, and similar) ($p < .01$); the similar condition was significantly different from the opposite condition ($p < .01$), the different condition ($p < .01$), and the asterisk condition ($p < .05$); and the asterisk condition was significantly different from the opposite condition ($p < .05$).

Table 3
Mean Pronunciation Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Five Treatment Conditions Used in Experiment 2 for High Frequency and Low Frequency Word Targets

Condition	Frequency	Latency	Error rate
Asterisk	H	507	4.0
	L	519	4.0
Opposite	H	522	1.0
	L	543	8.0
Different	H	508	3.0
	L	534	4.0
Similar	H	489	0.0
	L	502	5.0
Identical	H	460	4.0
	L	475	6.0

Note. H = high-frequency word targets; L = low frequency word targets.

The results clearly show, in the naming task, that targets preceded by identical primes were facilitated relative to the baseline condition, a graphemically dissimilar nonword prime, a graphemically dissimilar word prime, or a graphemically similar nonword prime. Furthermore, targets preceded by graphemically similar nonword primes were facilitated relative to targets preceded by the visual baseline condition, a nonword prime, and a graphemically dissimilar word prime. Finally, targets preceded by nonword primes were significantly inhibited relative to targets preceded by the baseline condition.

The analysis also revealed that high frequency target words (498 ms) had significantly faster naming latencies than low frequency targets (514 ms), $F(1, 9) = 25.07$, $MS_e = 565$, $p < .001$, and $F2(1, 96) = 7.25$, $MS_e = 5{,}451$, $p < .008$. All other interactions among the factors were not significant.

An analysis of the error data was also conducted. A two-way ANOVA (Condition × Frequency) revealed a main effect for frequency in the subject analysis, $F1(1, 9) = 5.87$, $MS_e = .38$, $p < .04$, but only a trend in the item analysis, $F2(1, 98) = 3.58$, $MS_e = .13$, $p > .06$. There tended to be fewer errors for high frequency targets (12 errors) than for low frequency targets (27 errors). There were no other significant main effects or interactions.

Task Analyses

Experiments 1 and 2 investigated graphemic priming effects in a lexical decision and a naming task. A 2 × 5 × 2 × 2 (Task × Condition × Frequency × Form Class) ANOVA performed to assess any differences in results due to task demands indicated that response times to targets in the naming task (506 ms) were significantly faster than response times in the lexical decision task (641 ms), $F1(1, 28) = 21.81$, $MS_e = 11{,}236$, $p < .001$, and $F2(1, 192) = 688.77$, $MS_e = 6{,}922$, $p < .001$.

As expected, the analysis also demonstrated that high frequency words (573 ms) in both the lexical decision and naming tasks were faster than the low frequency words (620 ms) in these tasks, $F1(1, 28) = 119.51$, $MS_e = 1{,}788$, $p < .001$, and $F2(1, 192) = 68.43$, $MS_e = 6{,}922$, $p < .001$. The size of the frequency effect was not equal across tasks, however. A much greater difference in reaction time obtained between high and low frequency words in the lexical decision task as compared with high and low frequency words in the pronunciation task. That is, there was a significant Task × Frequency interaction, $F(1, 28) = 40.14$, $MS_e = 1{,}788$, $p < .001$, and $F2(1, 192) = 23.95$, $MS_e = 6{,}922$, $p < .001$. High frequency words showed a 63-ms facilitation over low frequency words in the lexical decision task, whereas, in the naming task there was only a 16-ms difference between high and low frequency words. The Task × Condition interaction was not significant, $F1$ and $F2 < 1$.

Discussion

In the lexical decision task, identical prime–target pairs and graphemically similar prime–target pairs were significantly facilitated relative to graphemically different conditions. This pattern of results was observed in high as well as low frequency words. In addition, there were strong frequency effects—high frequency target words were facilitated relative to low frequency targets. The results for the naming task mimic those found in the lexical decision task. There was a strong effect found for frequency and, again, graphemically identical and graphemically similar primes produced speeded reaction times to targets compared with graphemically different prime conditions.

For the nonword targets in the lexical decision task, there was a significant effect of identity priming. Graphemically identical primes produced facilitation relative to all other prime conditions. However, unlike the results for the word targets, graphemic similarity did not produce facilitation in nonword targets. A possible explanation for this result is that, for word targets, graphemically similar primes only differed by one medial letter, whereas, for nonword targets, graphemically similar primes differed by as many as three medial letters. The simple fact of less graphemic overlap between prime and target for nonword targets compared with that for word targets may account for the difference in graphemic priming results.

Experiments 3 and 4: Associative Priming Effects

Experiments 3 and 4 investigated associative priming effects using the three-word masking paradigm in order to determine whether associative information can aid in lexical access. In these experiments, the associative relation of the prime word to the target was varied and reaction times to targets were then recorded. In two experimental conditions, a target (e.g., *DOCTOR*) was preceded either by an associatively related prime (e.g., *nurse*) or by an unrelated prime (e.g., *proof*). Two additional baseline conditions were included: a nonword prime condition (e.g., *chald*) and a baseline control (****).

It was hypothesized that associatively related primes would speed reaction times to targets in the three-word masking procedures. If, however, the three-word masking procedure only allows prelexical processing of the briefly presented primes, then facilitation to associatively related words would not be expected. Experiment 3 examined associative priming effects using a lexical decision task and Experiment 4 a naming task.

Experiment 3

Method

Subjects. Sixteen new students from the subject pool described in Experiment 1 participated in the experiment.

Stimuli. The stimuli consisted of 64 triplets in which the first item was a word mask, the second a prime, and the third a target. A complete list of all stimuli used in Experiment 3 is provided in Appendix B.

There were 64 target stimuli—32 word targets and 32 legal nonword targets. Targets were controlled for frequency of occurrence, form class membership, word length, and number of syllables. All nonword target items were legal nonwords. Nonword targets were also controlled for word length and number of syllables.

There were four prime conditions for the word targets (asterisk, nonword, unrelated, and related). Examples of each of the conditions for the word targets are given in Table 4.

In the asterisk condition, the prime was a string of four asterisks. For the nonword condition, the primes consisted of legal nonwords. In the unrelated condition, prime words were chosen so that they were not associatively related to the targets. In the related condition, primes were words associatively related to target items. A variety of associative relations were compiled from a number of word association norms (Goldfarb & Halpern, 1984; Palermo & Jenkins, 1964; Postman & Keppel, 1970; Shapiro & Palermo, 1969). All selected prime–target pairs were high associates; that is, target items were the primary responses to the prime words in the association norms. The related primes were matched to the unrelated primes for frequency of occurrence, form class membership, word length, and number of syllables.

The prime conditions and prime items for the nonword targets were the same as those used for the word targets (asterisk, nonword, unrelated, and related). Examples of each of the conditions for the nonword targets are given in Table 4. It should be noted that some of the conditions (e.g., unrelated and related) do not make sense when discussing nonword targets because the conditions refer to the associative relation between prime and target. However, because the unrelated and related primes were matched for a number of variables, it was interesting to determine whether there was any difference in their effect as "primes" upon nonword targets.

The mask or first word of the triplet was also controlled. Two separate lists (List A and List B) were used that were matched for frequency of occurrence, form class membership, word length, and number of syllables. Furthermore, semantic predictability of the mask with the prime and target was low.

Procedure. The procedure was identical to that used in Experiment 1.

Results

Mean lexical decision latencies and error rates for the four different conditions of Experiment 3 are provided in Table 5. There were 37 errors in this experiment, resulting in an overall error rate of 3.6%.

Because there were no significant main effects or interactions involving the list variable, data were collapsed over this variable. An ANOVA was performed on the lexical decision latencies to compare the unrelated with the related conditions for the word targets. Target items preceded by associatively related primes showed a substantial reduction in response latencies compared with targets preceded by unrelated primes, $F1(1, 15) = 12.51$, $MS_e = 1{,}030$, $p < .003$, and $F2(1, 31) = 8.11$, $MS_e = 3{,}486$, $p < .008$. Overall, targets in the related condition had mean reaction times of 595 ms, whereas targets in the unrelated condition had reaction times of 636 ms—a significant priming effect of 41 ms.

However, this priming was the result of both facilitatory and inhibitory effects. Relative to the baseline condition, reaction times to targets in the related condition were generally facilitated, whereas those in the unrelated and nonword conditions were generally inhibited, $F1(3, 45) = 3.79$, $MS_e = 1{,}330$, $p < .017$, and $F2(3, 93) = 3.35$, $MS_e = 3{,}533$, $p < .022$. Newman–Keuls post hoc tests revealed that targets in the related condition had significantly faster reaction times than targets in both the unrelated condition and the nonword condition ($p < .05$). These results suggest that associatively primes facilitated reaction times to target words, and nonword and unrelated primes inhibited reaction times relative to the baseline condition.

An ANOVA performed on the nonword data revealed no main effect for condition. As expected, there was no difference

Table 4
Examples of the Four Treatment Conditions Used in Experiment 3 for Both Word Targets and Nonword Targets

Target	Condition: Asterisk	Nonword	Unrelated	Related
	Word targets			
Mask word	bench	bench	bench	bench
Prime	****	chald	proof	nurse
Target	DOCTOR	DOCTOR	DOCTOR	DOCTOR
	Nonword targets			
Mask word	battle	battle	battle	battle
Prime	****	chald	proof	nurse
Target	TERWIN	TERWIN	TERWIN	TERWIN

Table 5
Mean Lexical Decision Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Four Treatment Conditions Used in Experiment 3 for Both Word Targets and Nonword Targets

Condition	Latency	Error rate
Word targets		
Asterisk	610	1.6
Nonword	626	3.1
Unrelated	636	3.1
Related	595	0.8
Nonword targets		
Asterisk	651	7.0
Nonword	649	4.7
Unrelated	645	3.9
Related	652	4.7

in associative priming effects among conditions for nonword targets (see Table 5).

In a combined word/nonword analysis, word targets (617 ms) were significantly faster than nonword targets (649 ms), $F1(1, 15) = 9.37$, $MS_e = 3{,}615$, $p < .008$, and $F2(1, 62) = 11.13$, $MS_e = 6{,}693$, $p < .001$.

An analysis of the error data was also conducted. A one-way ANOVA (Condition) for the word and for the nonword targets did not result in any significant effects.

Experiment 4

Method

Subjects. Sixteen new students from the subject pool described in Experiment 1 participated in the experiment.

Stimuli. The stimuli for Experiment 4 were the word stimuli that were used in Experiment 3. Thus, 32 word triplets were used in Experiment 4.

Procedure. The procedure was identical to that used in Experiment 2.

Results

Mean naming latencies and error rates for the four different conditions of Experiment 4 are given in Table 6. There were 17 errors in this experiment, resulting in an overall error rate of 3.3%.

An ANOVA was performed on the naming latencies to compare the unrelated condition with the related condition for the word targets. The mean reaction times for targets in the related condition were only 7 ms faster than those in the unrelated condition. This difference was not significant, $F1(1, 15) = 2.48$, $MS_e = 172$, $p > .10$, and $F2 < 1$.

Moreover, relative to the baseline, reaction times to targets in the other conditions were not significantly facilitated or inhibited. The four different prime conditions (asterisk, nonword, unrelated, and related) did not differentially affect pronunciation latencies, $F1(3, 45) = 1.18$, $MS_e = 364$, $p > .30$, and $F2 < 1$.

An analysis of the error data did not reveal any significant effects.

Task Analyses

Experiments 3 and 4 investigated associative priming effects in a lexical decision task and a naming task. A 2 × 2 (Task × Condition) ANOVA performed on the word data yielded a significant main effect of task, $F1(1, 30) = 34.61$, $MS_e = 9.591$, $p < .001$, and $F2(1, 62) = 169.95$, $MS_e = 3{,}901$, $p < .001$. As expected, overall mean reaction times to word targets in the naming task (474 ms) were faster than mean reaction times to words in the lexical decision task (617 ms).

There was also a significant Task × Condition interaction for the related and unrelated conditions in the subject analysis, $F1(1, 30) = 7.17$, $MS_e = 601$, $p < .012$, but this interaction showed only a trend in the item analysis, $F2(1, 62) = 3.33$, $MS_e = 2{,}665$, $p > .07$. Lexical decision tended to be more sensitive to the associative priming effects than naming.

Table 6
Mean Pronunciation Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Four Treatment Conditions Used in Experiment 4 for Word Targets

Condition	Latency	Error rate
Asterisk	473	3.1
Nonword	480	3.1
Unrelated	475	4.7
Related	468	2.3

Discussion

More robust associative priming effects were observed in the lexical decision task than in the naming task. Analyses of the lexical decision data showed significant priming effects due to the prior presentation of an associated word. Targets preceded by associatively related primes were, on average, 41 ms faster than targets preceded by an unrelated prime word. Relative to the baseline (asterisks), associatively related primes produced slight facilitation and unrelated primes produced slight inhibition, resulting in a combined contribution to the significant difference between related and unrelated conditions.

The picture was quite different for the naming latency data. Significant priming effects were not found for associated prime–target pairs. In naming, targets preceded by associatively related primes showed only a small, 7-ms facilitation relative to targets preceded by unrelated primes. Although the effect proceeded in the expected direction, the difference between related and unrelated prime conditions was not significant.

As expected, nonword targets were significantly slower than word targets in the lexical decision task. More important, nonword targets did not show the associative priming effects that were observed in word targets. At first glance, this seems a trivial outcome because nonwords do not have associative relations. However, this result does demonstrate that the associated prime words were relatively well-matched to their unrelated counterparts—at least in their "priming" effects on nonwords.

Experiments 5 and 6: Syntactic Priming Effects

Experiments 5 and 6 investigated syntactic priming effects. In these experiments, the prime word, when combined with both the mask and the target, formed a "sentence fragment" that was either syntactically appropriate or inappropriate. The purpose was to determine whether appropriate versus inappropriate syntactic information influenced lexical access time to target items at brief timing intervals.

Specifically, these experiments compared the effects of a modal verb prime on a verb (V) or noun (N) target word with the effects of a determiner or possessive pronoun prime on a verb (V) or noun (N) target word. By definition, a modal auxiliary is a word that precedes a verb and can serve as a signal that a verb will follow, very much as the presence of a determiner or possessive pronoun announces that a noun is coming. Making use of these syntactic relationships, two sentence fragment frames were devised (i.e., N-_____-V and V-_____-N) in which a modal auxiliary verb (MV) or either a determiner or a possessive pronoun (DET) was inserted. A modal auxiliary verb prime results in a syntactically appropriate sentence fragment for N-_____-V frames (i.e., N-MV-V), whereas a determiner prime does not (i.e., *N-DET-V). Conversely, for V-_____-N frames, a determiner prime results in a syntactically appropriate sentence fragment (i.e., V-DET-N), whereas a modal auxiliary verb does not produce a grammatical sentence (i.e., *V-MV-N).

The purpose of the present set of experiments was to investigate syntactic priming effects at short processing intervals in an attempt to achieve a better understanding of how a lexical item is incorporated into a preceding context. Using the three-word masking procedure, Experiment 5 examined syntactic priming effects in a lexical decision task and Experiment 6 made use of a naming task.

Experiment 5

Method

Subjects. Sixteen new students from the subject pool described in Experiment 1 participated in the experiment.

Stimuli. The stimuli consisted of 96 triplets in which the first item was a mask word, the second a prime, and the third a target. A complete list of all stimuli used in Experiment 5 is given in Appendix C.

There were 96 target stimuli—48 word targets and 48 legal nonword targets. For the word targets, half were high frequency (greater than 50 per million) and half were low frequency (less than 10 per million) (Francis & Kucera, 1982). Also, half the word targets were pure nouns, and the remaining half were pure verbs. The target words were matched for word length and number of syllables. There were 2 four-letter, 4 five-letter, and 6 six-letter words, of which 4 were monosyllabic and 8 were bisyllabic in each of the high frequency noun, high frequency verb, low frequency noun, and low frequency verb target groups. All nonword target items were legal nonwords. The nonword targets were matched to the word targets in word length and number of syllables.

There were four prime conditions for the word targets (asterisk, nonword, modal verb, and determiner). Examples of each of the conditions for word targets are provided in Table 7.

In the asterisk condition, the prime was a string of four asterisks. For the nonword condition, the primes consisted of legal nonwords. In the modal verb condition, primes were six different modal auxiliaries (i.e., may, can, must, might, could, and would). As modal auxiliaries, they had a mean frequency of occurrence of 1,670 per million. Two of the six modals were used only as modals, and although the remaining four have minor frequencies as other parts of speech (noun or verb), their frequency as modal auxiliaries constitutes more than 90% of their total frequency. In the determiner condition, primes were either singular determiners (i.e., this and that) or singular prenominal possessive personal pronouns (i.e., my, our , your, and their). They had a mean frequency of occurrence of 2,286 per million. All primes in this condition had no instances as other parts of speech except the word *that*, which can appear as a subordinate conjunction or a relative pronoun.

Table 7
Examples of the Four Treatment Conditions Used in Experiment 5 for Both Noun and Verb Targets and Nonword Targets

Target	Asterisk	Nonword	Modal verb	Determiner
		Noun targets		
Mask word	begin	begin	begin	begin
Prime	****	empty	could	this
Noun target	CIRCUS	CIRCUS	CIRCUS	CIRCUS
		Verb targets		
Mask word	tiger	tiger	tiger	tiger
Prime	****	catin	could	this
Verb target	PONDER	PONDER	PONDER	PONDER
		Nonword targets		
Mask word	tooth	tooth	tooth	tooth
Prime	****	ensip	could	this
Target	SORNEG	SORNEG	SORNEG	SORNEG

A congruent set of conditions between prime and target (asterisk, nonword, modal verb, and determiner) was constructed for the nonword targets (see Table 7). In all condition, the same items used as primes for word targets were also used as "primes" for the nonword targets. It should be noted that neither modal verbs nor determiners should, as primes, have any inherent facilitatory or inhibitory effect on nonword targets. However, the combination of the initial noun or verb mask with either the modal verb or the determiner prime, respectively, would be syntactically appropriate on 50% of the trials.

The mask or first word of the triplet was also controlled. When the target was a verb, the mask item was always a noun; when the target was a noun, the mask item was always a verb. This allowed for a complete syntactic "match" or "mismatch" of the three stimulus words. It should be noted that the three stimuli were constructed so that they were not semantically plausible but only syntactically appropriate combinations. The mask items were matched to target items for frequency of occurrence, word length, and number of syllables.

Procedure. The procedure was identical to that used in Experiment 1 except that the time interval between trials was 4 s.

Results

Mean lexical decision latencies and error rates for word targets in the four different conditions of Experiment 5 are given in Table 8. There were 73 errors in this experiment, resulting in an overall error rate of 4.8%.

A 2 × 2 × 2 ANOVA (Condition × Frequency × Form Class) performed on the lexical decision latencies to compare the modal verb condition with the determiner condition for word targets yielded a significant interaction of condition and form class, $F1(1, 15) = 6.61$, $MS_e = 3{,}887$, $p < .02$, and $F2(1, 44) = 6.42$, $MS_e = 5{,}403$, $p < .015$. Noun targets preceded by determiner primes (615 ms) were facilitated compared with noun targets preceded by modal verb primes (649 ms). Moreover, modal verb primes facilitated reaction times to verb targets (653 ms) compared with determiner primes preceding verb targets (676 ms). Clearly, the presence of a syntactically

Table 8
Mean Lexical Decision Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Four Treatment Conditions Used in Experiment 5 for Both Noun Targets and Verb Targets

Condition	Latency	Error rate
	Noun targets	
Asterisk	627	0.0
Nonword	664	5.2
Modal verb	649	5.2
Determiner	615	4.2
	Verb targets	
Asterisk	674	2.1
Nonword	687	9.4
Modal verb	653	7.3
Determiner	676	7.3

appropriate prime facilitated response latencies to target words.

However, this priming was the result of both facilitatory and inhibitory effects. Although, for noun targets, there was a tendency for nonword and modal verb primes to generally inhibit and determiner primes to generally facilitate reaction times relative to the asterisk condition and, for verb targets, there was a tendency for nonword and determiner primes to generally inhibit and modal verb primes to generally facilitate reaction times relative to the asterisk condition, the lack of a significant effect suggests that this priming was not very robust, $F1(3, 45) = 2.02$, $MS_e = 5{,}018$, $p > .10$, and $F2(3, 132) = 2.42$, $MS_e = 5{,}522$, $p > .05$.

As expected, high frequency targets (620 ms) had faster reaction times than low frequency targets (676 ms), $F(1, 15) = 24.37$, $MS_e = 4{,}043$, $p < .001$, and $F2(1, 44) = 14.20$, $MS_e = 5{,}352$, $p < .001$.

A 4 × 2 ANOVA (Condition × Initial Word) was also performed on the nonword data. Mean lexical decision latencies and error rates for the four different conditions of Experiment 5 are given in Table 9. For nonwords, prime condition did not significantly affect reaction times to target items, $F1(3, 45) = 1.09$, $MS_e = 2{,}248$, $p > .35$, and $F2 < 1$. However, stimulus trials having a verb as the first word (669 ms) were significantly faster than trials beginning with a noun (704 ms), $F1(1, 15) = 20.81$, $MS_e = 1{,}491$, $p < .001$, and $F2(1, 46) = 4.11$, $MS_e = 13{,}961$, $p < .04$.

Table 9
Mean Lexical Decision Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Four Treatment Conditions Used in Experiment 5 for Both Verb Initial and Noun Initial Nonword Target Trials

Condition	Latency	Error rate
	Verb initial	
Asterisk	693	1.0
Nonword	708	1.0
Modal verb	702	5.2
Determiner	703	8.3
	Noun initial	
Asterisk	724	5.2
Nonword	739	2.1
Modal verb	720	8.3
Determiner	748	4.2

The interaction (Condition × Initial Word) was not significant, $F1$ and $F2 < 1$. These results suggest that the form class membership of the first word in conjunction with a prime condition (asterisk, nonword, modal verb, and determiner) did not significantly influence reaction time to nonword targets.

In a combined word/nonword analysis, a main effect was found for word, $F(1, 30) = 5.70$, $MS_e = 42{,}380$, $p < .02$, and $F2(1, 92) = 23.52$, $MS_e = 14{,}564$, $p < .001$. As expected, word targets (656 ms) were significantly faster than nonword targets (717 ms).

An analysis of the error data was also conducted. For the word and for the nonword targets, a two-way ANOVA (Condition × Form Class) did not reveal any significant main effects or interactions. Although there were trends for condition for the word targets, $F1(3, 45) = 2.46$, $MS_e = .37$, $p > .08$, and $F2(3, 138) = 2.58$, $MS_e = .23$, $p > .06$, and for the nonword targets, $F1(3, 45) = 2.62$, $MS_e = .27$, $p > .06$, and $F2(3, 138) = 2.65$, $MS_e = .18$, $p > .05$, these effects did not reach significance.

Experiment 6

Method

Subjects. Sixteen new students from the subject pool described in Experiment 1 participated in the experiment.

Stimuli. The stimuli for Experiment 6 were the word stimuli (48 word triplets) used in Experiment 5.

Procedure. The procedure was identical to that used in Experiment 2 except that the intertrial interval was 4 s.

Results

Mean naming latencies and error rates for the four different conditions in Experiment 6 are provided in Table 10. There were 52 errors in this experiment, resulting in an overall rate of 6.8%.

A 2 × 2 × 2 ANOVA (Condition × Frequency × Form Class) was performed to compare the modal verb condition with the determiner condition. High frequency targets (474 ms) were responded to faster than low frequency targets (488 ms), $F1(1, 15) = 9.77$, $MS_e = 678$, $p < .007$, and $F2(1, 44) = 4.75$, $MS_e = 2{,}439$, $p < .035$. More important, however, the interaction between condition and form class, which was reliable in the lexical decision task, was not significant, $F1$ and $F2 < 1$. A modal verb prime did not facilitate reaction times to verb targets compared with a determiner prime for verb targets (a 3-ms difference), and a determiner prime did not facilitate reaction times to noun targets compared with a modal verb prime for noun targets (a 2-ms difference). Appropriate syntactic context did not speed response latencies to target words in the naming task.

Table 10
Mean Pronunciation Latencies (in Milliseconds) and Total Error Rates (Percentages) for the Four Treatment Conditions Used in Experiment 6 for Both Noun Targets and Verb Targets

Condition	Latency	Error rate
	Noun target	
Asterisk	470	4.2
Nonword	484	6.3
Modal verb	478	10.4
Determiner	476	10.4
	Verb target	
Asterisk	477	7.3
Nonword	500	5.2
Modal verb	487	7.3
Determiner	484	3.1

A comparison of the baseline with the experimental conditions also did not reveal any significant Condition × Form Class interactions, $F1$ and $F2 < 1$. Noun targets and verb targets had similar reaction times across all four prime conditions.

An analysis of the error data was also conducted. A two-way ANOVA (Condition × Form Class) did not reveal any significant effects.

Task Analyses

Experiments 5 and 6 investigated syntactic priming effects in a lexical decision task and a naming task. A 2 × 4 × 2 × 2 (Task × Condition × Frequency × Form Class) ANOVA indicated that words in the naming task (482 ms) were responded to much faster than the same word targets in the lexical decision task (655 ms), $F1(1, 30) = 80.10$, $MS_e = 48{,}101$, $p < .001$, and $F2(1, 88) = 395.60$, $MS_e = 7{,}470$, $p < .001$. There was also a significant Task × Frequency interaction, $F1(1, 30) = 36.31$, $MS_e = 1{,}925$, $p < .001$, and $F2(1, 88) = 6.43$, $MS_e = 7{,}470$, $p < .01$. That is, there was a significantly greater difference between high and low frequency words in the lexical decision task (high frequency words = 628 ms, low frequency words = 683 ms) as compared with high and low frequency words in the naming task (high frequency words = 478 ms, low frequency words = 486 ms).

There was also a significant Task × Condition × Form Class interaction for the modal verb and determiner conditions, $F1(1, 30) = 4.87$, $MS_e = 2{,}752$, $p < .035$, and $F2(1, 88) = 6.76$, $MS_e = 3{,}689$, $p < .011$. In the lexical decision task, verb targets preceded by a modal verb prime were facilitated compared with the determiner prime condition and noun targets preceded by a determiner prime were facilitated compared with the modal verb prime condition. In the pronunciation task, verb targets preceded by a modal verb prime were not facilitated compared with the determiner prime condition and noun targets preceded by a determiner prime were not facilitated compared with the modal verb prime condition. The lexical decision task showed a stronger effect of appropriate syntactic context compared with the naming data.

Discussion

The lexical decision data showed a significant interaction between prime condition and form class membership of the target. In the lexical decision task, noun targets were facilitated (34 ms) when preceded by determiner or pronoun prime words compared to modal verb primes, and verb targets were facilitated (23 ms) when preceded by modal verb prime words compared to determiner or pronoun primes. A syntactically appropriate prime context speeded lexical decisions to subsequent target words. These results, furthermore, were not frequency dependent, with both high and low frequency targets showing these effects.

The results for the naming task were quite different. Noun targets showed no priming effect of determiner primes compared to modal verb primes, and verb targets showed no priming effect for modal verb primes compared to determiner primes. A syntactically appropriate context did not facilitate pronunciation of subsequent target items. Moreover, neither high nor low frequency words showed a syntactic priming effect.

As well as being less sensitive to syntactic context, the naming task also showed substantially smaller differences between high and low frequency words compared with differences obtained in the lexical decision task. The lexical decision results showed a 55-ms frequency effect between high and low frequency target words, whereas the naming task only showed an 8-ms difference. This decrease in sensitivity to frequency in naming tasks has been observed previously (e.g., Forster & Chambers, 1973).

It was also found that nonword targets, as expected, were, on average, slower than word targets. Also, verb initial trials (703 ms) resulted in faster lexical decisions than noun initial trials (734 ms). This effect may be attributed to the fact that verb mask words had a mean frequency of occurrence of 119 per million, whereas noun mask items had a frequency of only 70 occurrences per million. Nevertheless, reaction times to nonword targets were not significantly affected by the syntactic acceptability of the preceding mask and prime word context.

General Discussion

The present experiments investigated graphemic, associative, and syntactic priming effects in both a lexical decision task and a naming task. The same experimental methodology, a three-word masking paradigm, was used in which the delay between prime and target onset time (60 ms) was minimal and the priming stimulus was masked in order to isolate and control effects on processing. By restricting the SOA in such a manner, the present experiments addressed a relatively early stage of word recognition. The discussion will first examine the results of the graphemic priming experiments, which show a similar pattern of priming in both the lexical decision and naming task. Then, the associative and syntactic data, which show a difference in priming across tasks, will be interpreted.

Graphemic priming effects (Experiments 1 and 2) were observed in both lexical decision and naming tasks. Words identical to target items showed strong priming effects relative to baseline conditions, and graphemically similar nonword prime items also showed significant, but less robust, priming effects for word targets. In the lexical decision task, nonword targets showed a significant facilitatory effect only when preceded by graphemically identical primes. Graphemically similar word primes did not facilitate reaction times to nonword targets.

These data share interesting similarities and differences with earlier reports. For example, Forster and Davis (1984), using the three-word masking paradigm, found robust identity (repetition) priming effects with word stimuli. However, they did not find *graphemic similarity* priming effects in word targets, which suggested to them that identity priming was most likely due to repeated access of the same lexical entry and was not the result of graphemic overlap between prime and target stimuli.

The results of Evett and Humphreys (1981) and Humphreys et al. (1987), however, lead to a different conclusion. Their data showed substantial graphemic priming effects although they used a different paradigm, a word identification task. Moreover, using the same three-word masking paradigm as Forster and Davis (1984), Forster et al. (1987) and Forster (1987) also obtained graphemic similarity priming effects. This effect, however, was observed only in prime–target pairs that were longer than six letters. Forster et al. (1987) and Forster (1987) suggest that length is probably not the critical factor but that density of the target neighborhood may be the determining factor. That is, longer words are generally located in low density neighborhoods and, consequently, have fewer competitors. Forster et al. (1987) conceded that graphemic similarity priming effects are probably not totally due to the repeated access of a single lexical item but are more likely the result of a range of candidates being activated simultaneously, a position more akin to activation theories of lexical access.

It should be noted that the present data were obtained using orthographically legal nonword primes preceding word targets. Primes and targets differed by only one medial grapheme. Moreover, targets were, on average, 5.5 letters in length. Although the present results appear to differ from the data presented by Forster (1987) and Forster et al. (1987), the type of prime conditions used across these studies provides an adequate explanation of the differences. As mentioned earlier, Evett and Humphreys (1981) and Humphreys et al. (1987) showed substantial graphemic priming effects in word targets, regardless of the lexical status of the prime. Moreover, when Forster (1987) and Forster et al. (1987) used nonword stimuli to prime word targets, robust graphemic priming was found in Experiment 1 of each study, but variable graphemic priming effects were found in Experiment 2 of each study. These results can be readily explained in terms of the orthographic regularity of the nonword primes. In Forster (1987, Experiment 1), as well as in the studies of Evett and Humphreys (1981) and Humphreys et al. (1987), only orthographically legal nonword primes were used, whereas in the latter two experiments (Forster, 1987, Experiment 2; Forster et al., 1987, Experiment 2) orthographically illegal letter strings were used. These results, in combination with the present results, strongly suggest that the use of orthographically legal nonword primes produces strong priming effects for graphemically similar word targets. Graphemic priming does not appear to be a purely lexical effect occurring only in identical prime–target word stimuli. These data suggest that the graphemic priming effect probably occurs at an early stage in word recognition.

For nonword targets, the present results also differ from those obtained by Forster and Davis (1984), Forster (1987), and Forster et al. (1987). Forster and colleagues found that nonwords did *not* show identity or graphemic priming effects. That is, graphemically related nonword primes did not speed reaction times to nonword targets. The data of Forster (1985) and the results of the present experiments, however, contradict these findings. Forster (1985) found significant graphemic identity priming effects for nonword targets relative to a control condition in which a graphemically unrelated word prime preceded the target nonword. Forster himself offers no explanation for this result. The present set of results supports the priming effects found in Forster (1985). In the present experiments, a graphemically identical prime preceding a nonword target significantly facilitated reaction times relative to both graphemically dissimilar word and nonword primes preceding the same nonword target.

The graphemic priming results for word and nonword targets uphold a model wherein graphemic priming effects appear to be due to abstract letter representations that are activated regardless of the word or nonword status of the prime. The present results for word targets also emphasize the importance of grapheme co-occurrence restrictions in these priming experiments. Previous studies had found that graphemic priming did not occur for word targets. However, it appears that the use of orthographically illegal nonword primes in those experiments may have produced the results. The use of orthographically regular primes seems to result in consistent and robust graphemic priming effects. This pattern of results is supported by recent research within the connectionist framework in which orthographic redundancy rules as coded in grapheme co-occurrence restrictions are able to account for some word recognition effects in naming and lexical decision performance (Brown, 1987; Seidenberg, 1989). Graphemic priming effects appear to result from the activation of abstract letter representations that are reinforced by regular letter co-occurrence restrictions.

Experiments 3 and 4 were devised to test whether subjects also access the lexical representation of prime words in the three-word masking paradigm by investigating whether associative relatedness produced reliable priming effects. Strong facilitatory effects of prime words on associatively related target words relative to unrelated controls were observed in the lexical decision task. However, data from the naming task did not exhibit such associative priming effects. Although the priming effects proceeded in the expected direction, the difference between the related and unrelated conditions was not significant in the naming task. The present pattern of results parallels that of previous researchers. At similar SOAs but with slightly modified presentation procedures, Fischler and Goodman (1978) found associative priming in a lexical decision task, but Warren (1977) and Carr, McCauley, Sperber, and Parmelee (1982) observed no facilitation of naming responses for associatively related stimuli.

It is possible that the difference in the associative priming effects across tasks may simply be due to time constraints.

Although both tasks may demand the operation of similar processes, it is feasible that the additional time needed to make a lexical decision permits further processing to take place. As noted above, lexical decision reaction times averaged 617 ms and naming latencies 474 ms.

If reaction times are delayed in the naming task, it is possible that pronunciation latency data might also show associative priming effects. This hypothesis was not supported by a reanalysis of the present data, however. In this reanalysis, the subjects were divided into two equal groups of "slow" subjects and "fast" subjects. Subjects who were slow to name targets (i.e., those having reaction times closer to subjects participating in the lexical decision task) did not show stronger associative priming effects than their faster counterparts (slow subjects: unrelated condition = 508 ms, related condition = 503 ms; fast subjects: unrelated condition = 442 ms, related condition = 433 ms). A more rigorous test of this hypothesis might be accomplished by using a response cutoff procedure in which subjects are given a fixed interval of time to respond. By systematically varying this response interval in lexical decision and naming tasks, a specific response interval may be found wherein lexical decision and naming responses are of compatible duration. If priming differences are still found between lexical decision and naming tasks at this response interval, then it could be more convincingly argued that the observed priming differences are probably not the result of additional processing time available in lexical decision tasks. Nevertheless, a preliminary analysis of the present associative priming results indicates that time to respond does not appear to be the crucial difference between lexical decision and naming tasks.

The syntactic priming results of Experiments 5 and 6 follow the pattern established in associative priming. Syntactic priming was observed for stimuli in the lexical decision task but not in naming. In these experiments, target items in the lexical decision task were facilitated when preceded by syntactically appropriate prime contexts, with modal verb primes speeding reaction times to verb targets and determiner and possessive primes speeding reaction times to noun targets. In lexical decision tasks, at least, syntactic information does appear to influence lexical access processes.

One of the most interesting findings of the present syntactic priming study is that a restricted masked context can produce priming for syntactically congruent target words in the lexical decision task at SOAs of 60 ms. It appears that robust syntactic priming effects are observable much earlier in processing than previous results have suggested. The present results demonstrate that syntactic priming effects are, in general, fast acting.

In the present syntactic priming experiments, the interval of time from prime onset to a subject's response averaged about 720 ms (i.e., a 60-ms prime duration plus a 660-ms response time) for word stimuli in the lexical decision task. If 200 ms is allowed for actual response execution, 520 ms remains for processing. Within this interval, lexical access of both prime and target must be accomplished. In addition, information concerning the appropriateness of the syntactic structure of these phrases must be made available. Evidence from shadowing tasks (Marslen-Wilson & Welsh, 1978), eye-movement experiments (Rayner, 1978), and evoked potentials (Van Petten & Kutas, 1987) indicates that a conservative estimate for lexical access is 200 ms (Rayner & Pollatsek, 1989). Assuming for simplicity a strictly serial model, these observations suggest that approximately 120 ms is available for syntactic information to be effective because 400 ms is presumably required for lexical access of prime and target. It appears, then, that syntactic context effects are influential almost immediately in word recognition. These data should encourage researchers to substantially reduce the often sizable intervals of time provided for syntactic processing.

At first glance, the pattern of results observed in the syntactic priming experiments appears to lend support to a modular, serial model of sentence processing (e.g., Cairns, 1984; Fodor, 1983; Forster, 1979; Tanenhaus, Carlson, & Seidenberg, 1985) in which higher level syntactic or semantic information does not affect processing at the lexical level because word recognition is distinct from and prior to processing of contextual information. Higher level contextual effects on word recognition processes have therefore been explained by appealing to a postlexical stage during which these interactions occur. Many observed contextual effects only influence lexical access in *lexical decision* tasks (e.g., Seidenberg et al., 1984; West & Stanovich, 1982). When other tasks such as naming or category verification are required, higher level contextual information does not seem to exert an effect on performance. On the basis of such data, it has been argued (Forster, 1979; Seidenberg & Tanenhaus, 1986; Tanenhaus et al., 1985; West & Stanovich, 1982) that many of the effects obtained in lexical decision arise at a postaccess decision stage that allows information from the syntactic and message processors to bias subjects' lexical response latencies.

The present syntactic priming results appear to support such an effect of postlexical processes which are operative in lexical decision but are not involved in naming tasks. However, it should be noted that the present data also showed task differences for associative priming. If an explanation based on postlexical effects is sufficient to account for the syntactic priming data, then such an explanation can also be invoked to describe the similar associative priming results. In such an account, associative relatedness, as well, would constitute higher level contextual information that can bias subjects' lexical response latencies at a postaccess decision stage in lexical decision tasks. This pattern of results is not compatible with a serial model of language processing that assigns associative effects to the lexical level.

The current literature has uncovered several important mechanisms that are involved in word recognition in addition to lexical access. These include backward priming and postlexical familiarity processes. These two operations will first be described and their involvement in the present series of experiments will then be discussed.

Attention has focused on the effects of backward priming on lexical decision and naming tasks. Recent studies (e.g., Koriat, 1981; Peterson & Simpson, 1989; Seidenberg et al., 1984) have suggested that backward priming effects may be able to account for some results in word recognition experiments. In backward priming, prime and target are processed such that access of the target influences the processing of the prime, prior to the subject's response to the target. Backward priming can be characterized as priming that arises only after target presentation.

In backward priming experiments, subjects are presented with prime and target pairs that are associated in one direction only, that is, either from prime to target in a forward direction or from target to prime in a backward direction. Although Koriat (1981) found equivalent forward and backward associative priming effects in a lexical decision task, Seidenberg et al. (1984) did not observe backward priming effects in a naming task. Recently, however, Peterson and Simpson (1989) presented data qualifying the conclusions of Seidenberg et al. (1984). Peterson and Simpson (1989) showed that backward priming can be obtained for both naming and lexical decision when shorter SOAs are used. Overall, then, it appears that both the naming and the lexical decision task are sensitive to backward priming effects.

A second factor that can account for recent results in word recognition studies is postlexical familiarity processes. There is good reason to suspect that the stages of processes required to make a lexical decision may be qualitatively different from those needed in the pronunciation task (for a review of the relevant literature, see Neely, in press). Effects obtained in the lexical decision task have been shown to originate at a decision or response stage that is not engaged in pronunciation (e.g., Balota & Chumbley, 1984, 1985; Chumbley & Balota, 1984; Lorch, Balota, & Stamm, 1986; Seidenberg et al., 1984; West & Stanovich, 1982). For example, the effect of word frequency proved to be significantly greater in the lexical decision task than in naming (Balota & Chumbley, 1984), as was also the case in Experiments 1 and 2 of the present study. These frequency effects have been explained by appealing to the influence of stimulus familiarity on the decision stage of tasks such as lexical decision. Briefly, the lexical decision task can be viewed as a familiarity discrimination task in which familiar words are to be discriminated from unfamiliar nonwords. Because low frequency words are more similar to nonwords on this familiarity dimension than high frequency words, the low frequency words are harder to discriminate (i.e., they produce longer response latencies) than high frequency words. Frequency effects, therefore, may be exaggerated in lexical decision tasks as a result of familiarity effects rather than lexical access operations because there often exists a confounding between the manipulated variable, frequency, and the familiarity of target words when subjects are required to make a lexical decision.

Such a postlexical familiarity strategy has also been invoked to explain other task-dependent effects (e.g., Balota & Lorch, 1986). According to such an account, after a target has been activated, but prior to when a lexical decision has been made, subjects determine whether the target is related or unrelated to the preceding prime word. If prime and target are related, a "word" bias results, facilitating responses to word targets. However, if prime and target are unrelated, a "nonword" bias results, inhibiting responses to unrelated word targets. Therefore, this postlexical discrimination strategy can produce facilitation for related prime–target pairs and inhibition for unrelated prime–target pairs that is not the result of lexical access processes.

Thus, evidence supporting backward priming effects and postlexical familiarity strategies suggests that, in many word recognition experiments, backward priming is operative in both naming and lexical decision and postlexical processes are operative primarily in lexical decision. It should be noted that these effects have been documented for experiments in which primes are unmasked and primes and targets are presented at relatively long SOAs. When primes are masked, however, the conditions change. It has generally been claimed that masked primes presented under near-threshold conditions dissociate automatic perceptual encoding mechanisms from conscious strategies (e.g., see Neely, in press). Consequently, the masked priming paradigm may be able to provide a relatively uncontaminated view of encoding mechanisms. It would appear, then, that masking the prime stimuli can attenuate backward priming processes. That is, reducing the availability of prime information restricts subjects from fully exploiting backward checking procedures.

The present masking procedure seems to have minimized the backward priming effects that occur in naming and lexical decision tasks when primes are unmasked. However, the postlexical processes that characterize lexical decision tasks are still operative. It appears that the associative and syntactic effects that are observed in the lexical decision task, but not in pronunciation, may be attributed to the operation of postlexical familiarity processes.

The present pattern of results for graphemic, associative, and syntactic priming in the naming and lexical tasks is consistent with a recent distributed model of word recognition developed by Seidenberg and McClelland (1989). This model accounts for the graphemic effects in naming and lexical decision and, following from the simulation of lexical decision in the network, also predicts the associative and syntactic priming effects in the lexical decision task.

In summary, then, the results of the present experiments in conjunction with recent experimental data indicate that graphemic priming is effective at an early stage of processing in both lexical decision and naming tasks. The present finding of observable graphemic priming in nonwords as well as words suggests that such priming effects are due to the activation of abstract letter representations and do not depend on lexical access.

The data for associative and syntactic priming, however, reveal a different pattern of results. Associative and syntactic priming were task dependent, producing priming effects in lexical decision but not in naming. The use of masked prime presentations, the attenuation of backward priming effects, and the differential sensitivity of these tasks to postlexical decision processes may provide a reasonable explanation for these results. In these experiments, masking seems to reduce the associative and syntactic priming that results from backward checking in both naming and lexical decision. However, because of the nature of the lexical decision discrimination task, associative and syntactic relatedness can be effective at a postlexical decision or response stage. Since a similar decision stage does not accompany the naming task, no priming effects are observed.

In retrospect, representations of lexical organization have radically changed since the early priming experiments. In the early studies, the variables of interest were word frequency and associative relatedness. These cardinal variables were intimately tied to the structure of the lexicon. Unfortunately, many of the experiments relied heavily on the lexical decision task to investigate lexical properties and, in many cases, fine-grained temporal analyses of the priming effects were not undertaken. Consequently, these experiments have provided a rather distorted view of lexical access processes. In recent years, however, more profitable approaches to the study of word recognition have been pursued. In the present study, using a single experimental paradigm, lexical decision and naming tasks that are differentially sensitive to experimental variables were employed. Also, stimuli were masked to minimize the availability of prime information. And, finally, time intervals between prime and target were carefully selected. These manipulations served to provide converging evidence concerning the nature of the internal lexicon and the distinct component processes involved in word recognition.

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Appendix A

Word and Nonword Stimuli Used in Experiment 1

Mask word	Opposite condition	Different condition	Similar condition	Target item	Mask word	Opposite condition	Different condition	Similar condition	Target item
blood	kilip	chain	warld	WORLD	assist	altow	goose	cercus	CIRCUS
freeze	dipit	pebble	charch	CHURCH	campus	gliker	listen	nizzle	NOZZLE
taxi	pote	seek	doar	DOOR	power	blask	scour	curgo	CARGO
fumble	blemir	holler	miment	MOMENT	gamble	peendo	heaven	cratch	CRUTCH
chisel	infead	device	porson	PERSON	shadow	sholk	token	inmote	INMATE
orbit	plord	rotor	masic	MUSIC	plunge	plabit	belong	tivern	TAVERN
click	creaf	exist	ruver	RIVER	murder	leckor	deduce	wullet	WALLET
forbid	dootis	linen	wondow	WINDOW	assert	sween	month	redent	RODENT
line	meap	road	trie	TREE	blaze	surp	wolf	cluwn	CLOWN
crouch	soudel	locust	dillar	DOLLAR	alert	bonik	begin	flisk	FLASK
summer	slutch	danger	peblic	PUBLIC	convey	tager	rebut	sondel	SANDAL
bloom	lufe	sing	trath	TRUTH	bench	saft	hill	mursh	MARSH
panic	kade	pave	gliss	GLASS	throat	cribon	radish	nipkin	NAPKIN
attain	crodle	valve	fature	FUTURE	finger	rictor	fill	corrot	CARROT
pocket	ensip	agent	ferest	FOREST	friend	fint	squint	pilley	PULLEY
branch	leabar	remain	cireer	CAREER	catch	chald	food	thenk	THINK
escape	renord	enrich	cuffee	COFFEE	bridge	prolit	wheat	fillow	FOLLOW
clerk	leard	earth	wigon	WAGON	ranch	spall	serve	cerry	CARRY
polish	keaver	ascend	torget	TARGET	keep	nart	plod	graw	GROW
plank	emply	apply	braen	BRAIN	hide	trep	task	sind	SEND
hunt	trab	stun	cird	CARD	pistol	bemmer	alley	decude	DECIDE
offer	logal	event	muvie	MOVIE	blame	gisto	hear	spund	SPEND
clutch	vilar	tariff	estote	ESTATE	block	mager	agent	occar	OCCUR
debate	walent	expand	cratic	CRITIC	lunch	bolly	fetch	preve	PROVE
handle	grost	cheat	vectim	VICTIM	humor	catin	hotel	tiach	TEACH
talent	clood	decade	menkey	MONKEY	wait	grep	menu	sove	SAVE
invade	soogel	stool	kutten	KITTEN	flavor	riener	inform	selict	SELECT
shine	pasil	enter	beist	BEAST	rustle	repret	incite	soffer	SUFFER
bride	panet	king	tirso	TORSO	police	tookip	aspect	sattle	SETTLE
budget	hettel	falcon	tirtle	TURTLE	exceed	lasin	tulip	insust	INSIST
strive	kosom	tooth	mosket	MUSKET	bubble	poeper	obtain	divade	DIVIDE
figure	labett	revert	grevel	GRAVEL	limit	drick	wince	argoe	ARGUE
drive	halit	speak	albem	ALBUM	pencil	mool	dinner	oppise	OPPOSE
nose	helt	atom	crub	CRIB	invite	seber	coffin	manuge	MANAGE
drop	zear	lurk	goot	GOAT	burden	shilon	adopt	engige	ENGAGE

Appendix A (*continued*)

Mask word	Opposite condition	Different condition	Similar condition	Target item	Mask word	Opposite condition	Different condition	Similar condition	Target item
thrive	ginth	endow	gother	GATHER	sample	goose	altow	oddity	ODNICE
spirit	fonest	tissue	prafer	PREFER	invent	speak	halit	woolen	WOOTIS
happen	fither	skull	remond	REMIND	clock	tooth	tager	snake	SNAIT
border	hoke	arrive	defand	DEFEND	charge	listen	gliker	ramble	REABLE
borrow	fegol	adhere	commat	COMMIT	patrol	belong	peendo	rocket	ROAKEN
grunt	coath	chair	anney	ANNOY	tumble	token	rictor	sandel	SARDEL
cash	selb	bulb	riam	ROAM	battle	deduce	leckor	tremor	TRAMET
huddle	goakka	forget	storve	STARVE	devote	squint	surp	renter	RENSOR
bread	roath	bird	snaff	SNIFF	shake	wolf	bonik	atone	ATRON
cloud	atron	expel	grize	GRAZE	labor	rebut	sween	flunk	FLINK
build	vimit	fiber	spoll	SPILL	preach	begin	fint	obtuse	OBTISK
mirror	sarlin	pulpit	bestaw	BESTOW	climb	month	blask	plate	PLAVE
expose	gress	locate	concir	CONCUR	master	heaven	cribon	albino	ALBING
lesson	carnot	impel	assoil	ASSAIL	bullet	fill	zear	trip	TROZ
inject	nacade	crisis	offond	OFFEND	chance	radish	plabit	luster	LOSTER
cement	arsek	trait	pinder	PONDER	score	serve	lasin	glint	GLANT
help	rull	shut	laer	LEER	flower	fetch	prolit	bitter	BIPPER
curve	gater	doze	avurt	AVERT	haunt	skull	catin	quart	QUARP
finish	racal	belief	clanch	CLENCH	chin	hear	trep	lisp	LURP
mouth	koner	tiger	civet	COVET	hold	plod	nart	vote	VORG
carpet	flazik	tell	aspare	ASPIRE	plenty	wheat	mool	duster	DISTER
accept	fouth	falter	biffle	BAFFLE	burst	food	gret	spent	SPONT
mingle	hinsup	floor	sommer	SIMMER	image	agent	mager	groin	GLOIN
nest	drig	idol	mund	MEND	raise	endow	seber	satin	SARUN
expect	laypek	bring	rediem	REDEEM	shoot	alley	chald	notch	NOUCH
amount	brish	hustle	infact	INFECT	coat	task	hoke	plot	PLEF
murmur	credlo	speech	honder	HINDER	factor	inform	tookip	flower	FLOMER
winter	nost	booth	sazzle	SIZZLE	profit	obtain	bemmer	jargon	JARTON
appear	zarter	learn	kudnap	KIDNAP	market	dinner	fonest	bemoan	BETTAL
lumber	pove	impede	wather	WITHER	prison	tulip	bolly	offset	OFFOST
party	chain	plord	valet	VAPET	button	coffin	repret	donkey	DONTER
letter	holler	kilip	couple	CORPLE	crush	menu	spall	armor	ARNOR
ship	seek	kade	plum	PLAM	center	adopt	shilon	remain	REMPOT
bounce	pebble	blemir	gutter	GULTAN	launch	hotel	ginth	planet	PLARET
wiggle	ascend	dootis	nossle	NUSTLE	chorus	tissue	poeper	bubble	BOWBLE
court	device	dipit	bison	BITON	differ	incite	gisto	clause	CLATIG
table	rotor	creaf	strip	STRIG	muscle	arrive	riener	kernal	KEAMAN
direct	earth	ensip	blazon	BLUKIN	infant	aspect	drick	played	PLABET
cave	stun	lufe	bust	BIST	repeat	wince	fither	ferric	FERGIN
bellow	locust	infead	midget	MIGLEN	excite	adhere	fegol	duster	DOSKER
parent	danger	slutch	crease	CROISE	beard	expel	atrot	plank	PLARK
assure	remain	trab	sordid	SOABIT	drip	bulb	selb	vast	VISP
drape	agent	logal	boast	BOLET	employ	hustle	goakka	margin	MARLET
derive	event	meap	curfew	CURFIN	lobby	bird	roath	ninth	NANTH
father	cheat	soudel	assent	AKMENT	boast	chair	vimit	spree	SPRUP
needle	pave	renord	trench	TREPER	plant	impel	gress	total	TOTOR
tunnel	enrich	crodle	sonnet	SORNEG	shovel	falter	coath	memoir	MEPSIG
fence	valve	grost	blunt	BLENT	shiver	locate	zarter	credit	CRASIT
jacket	apply	leabar	outlet	OSTREM	nature	tiger	koner	rescue	RISCUT
glove	exist	leard	prean	PREAK	region	sppech	laypek	dinner	DINCAP
beat	road	pote	cram	CRON	wonder	crisis	carnot	asleep	ASTEEP
grill	linen	vilar	awful	ARFIT	fist	tell	nost	dolt	DOOT
throw	sing	emply	worth	CORTH	reduce	impede	racal	gurgle	GURKLE
regret	tariff	walent	camera	CALARK	signal	trait	flazik	pardon	PARBIN
snatch	expand	keaver	shovel	SHOKET	blush	bring	arsek	paste	PEATH
absorb	enter	pasil	valley	VOBGET	become	fiber	rull	spigot	SPIGOL
bottle	stool	labett	terror	TERWIN	cradle	doze	nacade	cornet	CORBAT
stand	scour	kosom	clout	CLOOT	refine	booth	gater	orate	ORKLE
anger	king	panet	moist	MAINT	skin	idol	pove	spit	SPET
scream	revert	hettel	banter	BANTEN	artist	shut	drig	dream	DREAT
wealth	falcon	clood	hectic	HESTIM	caress	floor	hinsup	lumber	LUNTER
reason	decade	soogel	cuddle	CUBBLE	burden	forget	credlo	oppose	OMPOST
avail	hill	sholk	retch	RETIS	credit	pulpit	brish	shiver	SHIGER
fork	lurk	helt	seed	SMED	mumble	belief	sarlin	copper	CODVER
pull	atom	saft	blur	BLUN	corner	learn	fouth	helmet	HILNET

(*Appendixes continue on next page*)

Appendix B

Word and Nonword Stimuli Used in Experiment 3

Mask word	Nonword condition	Unrelated condition	Related condition	Target item	Mask word	Nonword condition	Unrelated condition	Related condition	Target item
blood	zoc	lot	bed	SLEEP	party	zoc	lot	bed	FLINK
taxi	kad	law	boy	GIRL	ship	kad	law	boy	PLAM
campus	grost	noise	bread	BUTTER	letter	grost	noise	bread	CORPLE
orbit	caf	eat	buy	SELL	court	caf	eat	buy	CRON
summer	lut	job	car	TRUCK	prison	lut	job	car	PREAK
panic	leard	youth	chair	TABLE	cave	leard	youth	chair	BOLET
branch	hoke	fact	city	TOWN	parent	hoke	fact	city	SMED
line	tep	leg	dog	CAT	father	tep	leg	dog	BIST
pocket	peen	kind	door	WINDOW	plenty	peen	kind	door	GULTAN
clerk	chal	seem	find	LOSE	wealth	chal	seem	find	BLUN
plank	drick	flesh	fruit	APPLE	jacket	drick	flesh	fruit	BIPER
talent	ser	bit	gun	SHOOT	glove	ser	bit	gun	CORTH
budget	bist	life	hand	FOOT	bottle	bist	life	hand	LURP
chisel	nar	sky	hat	COAT	grill	nar	sky	hat	TROZ
power	shil	road	head	HAIR	anger	shil	road	head	PLEF
nose	rien	food	king	QUEEN	tunnel	rien	food	king	STRIG
bride	fith	item	lion	TIGER	reason	fith	item	lion	RETIS
murder	goak	tree	moon	STAR	fork	goak	tree	moon	VORG
figure	roath	stove	mouse	CHEESE	sample	roath	stove	mouse	KROISE
shadow	cred	pond	nail	HAMMER	clock	cred	pond	nail	SORNEG
bridge	blemir	silver	needle	THREAD	charge	blemir	silver	needle	CHRANT
throat	dootis	world	number	LETTER	patrol	dootis	world	number	CALARK
bench	chald	proof	nurse	DOCTOR	battle	chald	proof	nurse	TERWIN
finger	gress	client	priest	CHURCH	labor	gress	client	priest	THRINT
friend	bolly	story	river	WATER	master	bolly	story	river	HELIT
ranch	emp	pie	rug	CARPET	bullet	emp	pie	rug	TRAMET
pistol	vil	ask	run	WALK	chance	vil	ask	run	DOOT
block	pish	lake	salt	PEPPER	flower	pish	lake	salt	RENSOR
humor	sarl	desk	stem	FLOWER	chin	sarl	desk	stem	LOSTER
lunch	kess	come	take	GIVE	fence	kess	come	take	VISP
burden	hal	ink	web	SPIDER	image	hal	ink	web	JARTON
police	loat	hose	wool	SHEEP	factor	loat	hose	wool	NOUCH

Appendix C

Word and Nonword Stimuli Used in Experiment 5

Mask word	Nonword condition	Modal verb condition	Determiner condition	Target item	Mask word	Nonword condition	Modal verb condition	Determiner condition	Target item
hear	pote	can	your	WORLD	decade	pote	can	your	VAPET
enter	lufe	must	our	DOOR	food	lufe	must	our	PLAM
clasp	kade	may	my	TREE	stool	kade	may	my	BIST
impede	plord	might	their	RIVER	wheat	plord	might	their	VIMIT
serve	kilip	could	this	PERSON	falcon	kilip	could	this	GULTAN
carry	dipit	would	that	PUBLIC	alley	dipit	would	that	OBTISK
fetch	trab	can	your	GLASS	king	trab	can	your	STRIG
shut	helt	must	our	FOREST	task	helt	must	our	AKMENT
define	saft	may	my	CARD	wolf	saft	may	my	CRON
enrich	creaf	might	their	TARGET	error	creaf	might	their	OSTREM
incite	ensip	could	this	COFFEE	tooth	ensip	could	this	SORNEG
scour	logal	would	that	ESTATE	hotel	logal	would	that	DISTER
forget	leard	would	that	MONKEY	goose	leard	would	that	VOBGET
cheat	surp	can	your	BEAST	menu	surp	can	your	CLOOT
fill	fint	must	our	CRIB	atom	fint	must	our	CRED
deduce	grost	may	my	ALBUM	aspect	grost	may	my	CORTH
adopt	vilar	might	their	TURTLE	token	vilar	might	their	BANTEN
begin	emply	could	this	CIRCUS	tulip	emply	could	this	ODNICE
endow	pasil	would	that	CARGO	month	pasil	would	that	ATRON
seek	meap	can	your	INMATE	dinner	meap	can	your	ROAKEN
flap	zear	must	our	WALLET	hill	zear	must	our	TRAMET
rebut	kosom	may	my	CLOWN	coffin	kosom	may	my	PLAVE
learn	labet	might	their	MARSH	heaven	labet	might	their	GRESS
expel	clood	could	this	CARROT	tissue	clood	could	this	CUBBLE
chain	meap	can	your	THINK	tell	meap	can	your	QUARP
bulb	nart	must	our	SAVE	obtain	nart	must	our	PLEF
pebble	trep	may	my	SEND	squint	trep	may	my	VORG
chair	altow	might	their	DECIDE	holler	altow	might	their	CREDLO
device	sholk	could	this	PROVE	locate	sholk	could	this	SKENT
fiber	panet	would	that	CARRY	allow	panet	would	that	KONER
rotor	mool	can	your	SUFFER	pave	mool	can	your	JARTON
bird	gret	must	our	INSIST	sing	gret	must	our	OFFOST
road	hoke	may	my	ARGUE	skim	hoke	may	my	ARNOR
pulpit	halit	might	their	MANAGE	attend	halit	might	their	PLARET
linen	tager	could	this	GATHER	settle	tager	could	this	CLATIG
crisis	somik	would	that	REMIND	ascend	somik	would	that	PLABET
locust	selb	would	that	ANNOY	impel	selb	would	that	GOKKA
trait	nost	can	your	STARVE	shun	nost	can	your	BONICK
danger	sween	must	our	GRAZE	propel	sween	must	our	SPRUP
belief	blask	may	my	BESTOW	expect	blask	may	my	MEPSIG
valve	lasin	might	their	ASSAIL	bring	lasin	might	their	RISCAT
tiger	catin	could	this	PONDER	apply	catin	could	this	FLOMER
agent	mager	would	that	AVERT	hustle	mager	would	that	ARNEP
idol	rull	can	your	COVET	stun	rull	can	your	RETIS
earth	pove	must	our	MEND	adhere	pove	must	our	DOOT
floor	sebar	may	my	BAFFLE	expand	sebar	may	my	DONTER
event	gisto	might	their	INFECT	revert	gisto	might	their	OMPOST
speech	chald	could	this	KIDNAP	belong	chald	could	this	CODVER

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